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Effect of Seed Priming on Agronomic Performance of Rice (*Oryza sativa* L.) Variety C26

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A B S T R A C T

Rice is a staple food for many people and a source of currency for many farmers. However, in West Africa, yields remain low. One of the reasons is the unsuitability of cultivation techniques, which results in heterogeneous germination of seedlings and low yields. The aim of this study was to evaluate the agronomic performance of rice variety C26 after seed priming. Rice grains were primed in various solutions. The resulting seeds were sown in a randomized block design with three replications in each cropping system (lowland and rainfed). Treatments were a control (no priming) and seed priming (NaCl; sucrose and Water). Sucrose and water priming were better in both growing systems. The NaCl system recorded the lowest agronomic parameter values. In the lowland, the emergence percentage was 95%. Emergence time at 50% (T50) varied between 6.6 and 11.10 days. The number of thalli and plant height increased from 7.22 to 9.50 thalli and from 30.28 to 50 cm respectively. Yield improved from 2362.17 kg/ha for the control to 3666.67 with sucrose priming and 4222.50 kg/ha with water priming, an increase of almost 50%. In rainfed conditions, emergence percentages ranged from 90 to 96%. T50 varied between 3.27 and 4.9 days. The number of thalli and plant height increased from 6.78 to 8.44 thalli and from 31 to 34 cm respectively. Yield increased by around 50%, from 1353.83 (control) to 2400.81 kg/ha with sucrose and 2844.62 kg/ha with water. The study shows that priming with water and sucrose significantly improves the agronomic performance of rice variety C26.

Introduction

Rice is a high-priority product for food security in Africa (Seck *et al.*, 2013; FAO, 2020). In recent years, the food situation in African countries has been strongly impacted by the COVID19 crises and the war in Ukraine. This situation has raised awareness of food self-sufficiency among the populations of our vulnerable countries.

Despite the efforts made by various countries, West African rice production covers only 50-60% of demand (Levard *et al.,* 2021). To make up this shortfall, countries resort to massive imports of milled rice worth nearly 15 million tons a year. These imports cost African countries more than CFAF 3,000 billion a year, which represents a considerable loss of the continent's foreign currency reserves (Africa Rice, 2022). In response to this situation, African countries have implemented strategies to intensify rice cultivation.

Despite these efforts, rice production is faced with several biotic (weeds, vertebrate pests and pathogens) and abiotic constraints, such as uncontrolled rainy seasons due to the effects of climate change, which make rice cultivation very arduous in a context where its production depends essentially on rainfall (Tajani *et al.,* 1997; Fall, 2018). Under these conditions, the solutions recommended to increase rice production have been to control sowing densities with good soil management, suitable irrigation and intercropping of rice varieties (Lamrani *et al.,* 2012). To limit losses due to biotic constraints, reduced nitrogen input remains an effective method (Tajani *et al.,* 2001).

Despite these known solutions, yields remain low. Studies have shown that agricultural production is closely linked to the seeds used to establish the crop. Some of the reasons for poor production include induced seed dormancy and non-synchronous germination (Boucelha & Djebbar, 2015).

Thus, several authors have advocated the use of pre-germinative treatments, such as seed priming. This alternative approach has variously been applied to a variety of seeds and has improved the agronomic parameters of beans; wheat; maize and rice (Mc Donald *et al.,* 2000; Boucelha & Djebbar, 2015). This approach involves soaking seeds in a hydric, osmotic, hormonal or chemical solution (Bradford, 1986).

However, in West Africa, very few studies have focused on this approach, mainly on rice. For this reason, this study was initiated to evaluate the influence of different types of priming on germination, growth and production of rice variety C26 under lowland and rainfed conditions. Specifically, the aim was to:

(i) evaluate the effect of each type of priming on germination of rice variety C26 under each growing condition;

(ii) evaluate the effect of each type of priming on the growth of rice variety C26 under each growing condition; (iii) evaluate the effect of each type of priming on the production of rice variety C26 under each growing condition.

Materials and Methods

Plant Material

Grains of variety C26 (Figure 1) of the species *Oryza sativa* L. were supplied by AMC-FC (Agricultural and Management Company Food and Commerce) based in Yamoussoukro, central Côte d'Ivoire. This variety was chosen because of its good taste, which makes it popular with the local population. It is tolerant to lodging, has a low aroma and long kernels. Its cycle is 102 days and adapted to rainfed and lowland conditions with a potential yield of 7.5 t/h (CORAF, 2018).

Research into priming time

The seeds received from AMC-FC were sorted to remove damaged seeds and unwanted particles. Before soaking them in the solutions used for priming, it was necessary to determine the average germination time of the grains. This time corresponds to the precise moment when the radicle appears. These seeds were placed in 6 Petri dishes containing blotting paper moistened with distilled water.

Incubation took place at room temperature (27±1°C). The time of the tip of the first radicle in each dish was recorded. The mean time of the first rootlet tip (X) and the standard deviation (σ) were determined. The initiation time was determined by subtracting from the mean (X), the standard deviation (σ) plus 2 hours [X - (σ+2)] to ensure that the reversible phase had not been exceeded (method of Farooq *et al.,* (2006) adapted). Thus, the selected time was 43 hours.

$$\sigma = \sqrt{\frac{\sum(x_i - \mu)^2}{N}}$$

with:

xi is the peak time of the Petri dishes;

μ is the mean of the Petri dishes;

N is the number of Petri dishes;

(σ) is the standard deviation.

Seed priming

Batches of 0.5 kg seeds were formed and each was soaked in 1.5 liters of priming solution for 43 hours, following the protocol of Farooq *et al.,* (2006). The first batch of seeds (priming T0) consisted of unsoaked control seeds, the second batch (T1) was soaked in distilled water, the third batch (T2) was soaked in a NaCl solution (58.4 g/L) and the fourth batch (primer T3) was soaked in sucrose solution (60 g/L).

Parameters Evaluated

Once the experiment had been set up, emergence, growth and yield parameters were evaluated.

These were latency time (TL) to emerge from the soaking solution, emergence percentage (EP), germination index (GI), emergence mean time (EMT), emergence duration (ED) and time to 50% emergence (T50E), number of tillers (NT), number of leaves (NL), culm height (CH) and collar diameter (CD). Growth parameters were assessed at plant set and heading. Yield parameters were: heading time (HT), heading duration (HD), maturation duration (MD), weight of 1 grain (W1G), weight of 1000 grains (W1000G) and grain yield per hectare (GYH).

Experimental set-up and statistical analyses

The design adopted in both experiments was a randomized Fisher block design with three replications. Each block was composed of four elementary plots of 6 m² (3m x 2m) each. Each plot comprised one treatment, and the treatments were made up of the type of rice priming (Control, water priming, sucrose priming and NaCl priming). This was done for each cropping system (rainfed and lowland). Spacing between sowing points was 20 cm by 20 cm.

The data collected were analyzed using STATISTICA version 7.1 software. The conditions for carrying out the analysis of variance were verified. Each treatment had a size of 36 individuals, so the population was assumed to be normal. The homogeneity of variance test was then carried out using Bartlett's test at the 5% threshold. Analysis of variance (ANOVA) with one factor (priming types) was performed to assess their influence on the various parameters evaluated. When this analysis showed a difference between the means, Tukey's HSD test at the 5% threshold was performed to classify the different means. However, for index and proportion data, the non-parametric Kruskal-Wallis test was adopted.

Results and Discussion

Effect of priming type on rice seed emergence parameters

Priming had a significant influence on germination parameters in lowland ($P < 0.001$) or rainfed ($P < 0.01$) conditions.

In lowland conditions

Table 1 shows that emergence parameters of rice seeds sown in the lowland after priming were improved. Emergence percentage (EP) increased from 65.09% to 95-96%. Similarly, germination index (GI) was highest with these treatments. Time to 50% emergence (T50E), emergence duration (ED) and latency time (LT) were reduced. Seeds primed with NaCl had a lower emergence percentage (EP) (58.90%) and a higher T50E (11.10 days).

Rainy conditions

Emergence parameters under rainfed conditions are presented in Table 2. As in lowland conditions, the type of seed priming had a significant influence ($P < 0.01$) on these emergence parameters. Sucrose and water priming favored these emergence parameters. With sucrose and water respectively, emergence percentages were 91.29 and 95.42%, and germination indices were 33.61 and 59.37 respectively. On the other hand, priming with sucrose and water caused a reduction in emergence time to 50% (4.31 and 3.27 days), emergence duration (5.72 and 6.66 days), mean emergence time (8.94 and 7.83 days) and latency time (1.63 days) respectively.

Influence of rice grain priming on growth parameters

Results on the influence of priming type on growth parameters are shown in Tables 3 and 4. These results indicate that the type of priming has a significant influence ($p < 0.001$) on growth parameters in both lowland and rainfed conditions. Sucrose and water priming favored thallus production (NTS), leaf production (NFS) and plant height (PHS). However, plants obtained from seeds primed with NaCl had the lowest numbers of thallus and leaves, and the smallest plant size. In lowland conditions, the number of thalli at fruit set was 9 for around 50 to 55 leaves produced. The minimum height was 50 cm.

When the plants were in rainfed conditions, the number of thalli varied between 6.78 and 8.44, for 42.61 to 45.83 leaves produced. Plant height ranged from 31 to 34 cm at fruit set.

Figure 2 shows rice plants aged one month after sowing under the different treatments. Lowland plants had the highest number of tillers, leaves and stubble height compared with rainfed plants. The best agronomic performances were obtained with water priming, followed by sucrose. NaCl priming gave virtually the same performance as the control.

Influence of priming on production and yield parameters

Figure 3 shows the time to first ear (TFE), the time to heading (TH) and the time to maturity (TM) of plants from primed seeds under lowland and rainfed conditions. The values of these parameters were higher under rainfed conditions than under lowland conditions. Also, these values were lower when priming was carried out with water and sucrose. Under rainfed conditions, the time to first ear was 66.83 days with water priming and 71.39 days with sucrose. In the lowlands, time to first ear was 65.22 days with water and 67 days with sucrose. The ear emergence time (ET) was 6.22 days with water and 8.06 days with sucrose in lowland conditions, and 5.89 days with water and 8.39 days with sucrose in rainfed conditions.

Yield

A priming effect was revealed on the weight of one grain (W1G), the weight of 1000 grains (W1000G) and grain yield per hectare (GYH). The best production was obtained with water priming (3666.67 kg/ha) followed by sucrose (4222.50 kg/ha) in the lowland and rainfed areas, at 2844.62 and 2400.81 kg/ha respectively. Production remained low with NaCl priming and with the control (Tables 4 and 5). Good crop productivity is closely linked to good seed germination. No amount of fertilizer can increase crop production if the seed is not of good quality. This study was conducted to assess the consequences of applying different types of priming on germination, the different phenological phases and yield of a rice variety grown in lowland and rainfed upland conditions.

Germination percentage was higher with water and sucrose priming in both cropping systems. This result could be due to the fact that grains soaked in water and sucrose solution absorbed sufficient water to initiate the germination metabolism, as water uptake constitutes the first phase of germination. A synchronization of germination is obtained according to the duration of germination with water. This is explained by the fact that water activates pre-germination processes, triggering quantitative and qualitative biochemical changes in the seed, such as membrane repair and nucleic acid synthesis (DNA and mRNA). These results are similar to those reported by Janmohammadi *et al.,* (2008) on rice. These studies showed that priming stimulates hydrolysis of cotyledonary protein and carbohydrate reserves. Physiologically, water priming results in strong synthesis and activation of enzymes involved in the degradation and mobilization of protein (proteases) and carbohydrate (alpha amylase) reserves. The products of this hydrolysis (amino acids and soluble sugars) will be used during germination. Low germination percentages were observed with NaCl priming. This could be explained by the fact that the concentration of NaCl used would have limited grain imbibition. Bourgne and Job (2000) have shown that salinity inhibits germination through its osmotic effect, affecting all germination processes following a drop in grain water potential.

With regard to the cropping system, emergence time at 50%, germination time and mean germination time were longer in the lowland than in the rainfed system. This may be due to the fact that the seeded grains were in excess water conditions. This would have delayed seed emergence. A study carried out on rice by Diedhiou (2019) showed that the germination phase lasts from 5 to 20 days (5 days under normal hydrometric conditions and 20 days under low temperatures with waterlogged soils).

The influence of priming and growing system on growth parameters was accentuated with water and sucrose priming. In terms of culm height, number of leaves and number of thalli, both water and sucrose priming had a positive effect on these parameters. These results can be explained by the fact that, since water solubilizes the minerals contained in the soil, these minerals are easily absorbed by the plant. This, in turn, would promote good plant development.

Table.1 Influence of rice seed priming on emergence parameters in lowlands

TP	EP(%)	T50E (Day)	GI	ED(Day)	EMT(day)	LT(day)
Control	65.09 ± 2.51^{b}	10.70 ±1.16^{a}	12.47 ± 0.22^{c}	8.11 ± 0.96^{a}	12.67 ± 0.69^{ab}	6.60 ± 0.52^{a}
NaCl	58.90 ± 6.61^{b}	11.10 ± 0.99^{a}	13.32 ± 0.77^{c}	6.06 ±1.30^{b}	11.39 ± 1.85^{b}	5.30 ± 0.82^{b}
Sucrose	95.70 ± 2.26^{a}	8.40 ± 0.70^{b}	18.38 ± 0.74^{b}	5.39 ±0.61^{b}	13.28 ± 1.23^{a}	5.60 ± 0.52^{b}
H_2O	96.40 ± 1.26^{a}	6.6 ±0.79^{b}	19.62 ± 0.32^{a}	4.22 ± 0.94^{c}	12.44 ± 2.62^{ab}	4.50 ± 0.71^{c}
P	< 0.001	< 0.001	< 0.001	< 0.001	0.016965	< 0.001

Legend: TP : Type of priming; EP : Emergence percentage; T50E : time to 50% emergence ; *GI : Germination index; ED : Emergence duration ; EMT : Emergence mean time ; LT : Latency time ; For a column, means (± standard deviation) followed by the same letter are statistically identical at the 5% threshold.*

Table.2 Influence of rice seed priming on emergence parameters in rainfed conditions

TP	EP(%)	T50E (day)	GI	ED(day)	EMT(day)	LT(day)
Control	73.16 ± 2.32^{c}	4.90 ± 0.20^{a}	25.68 ± 0.42^{c}	15.61 ± 1,04^{a}	9.39 ± 1.54^{b}	3.75 ± 0.89^{a}
NaCl	50.60 ± 2.29^{d}	4.28 ± 0.12^{b}	18.57 ± 0.51^{d}	10.17 ± 0.92^{b}	10.89 ± 1.23^{a}	2.50 ± 0.53^{b}
Sucrose	91.29 ± 1.58^{b}	4.31 ± 0.31^{b}	33.61 ± 1.68^{b}	5.72 ± 0.75^{c}	8.94 ± 1.16^{bc}	1.63 ± 0.74^{c}
H_2O	95,42 ± 2,75^{a}	327 ± 0.16^{c}	59.37 ± 1.31^{a}	6.66 ± 1.57^{c}	7.83 ± 2.36^{c}	1.63 ± 0.74^{c}
P	< 0.001	0.007	< 0.001	< 0.001	< 0.001	< 0.001

Legend: TP: Type of priming; EP: Emergence percentage; T50E : time to 50% emergence ; *GI : Germination index; ED : Emergence duration ; EMT : Emergence mean time ; LT : Latency time ; For a column, means (± standard deviation) followed by the same letter are statistically identical at the 5% threshold.*

Table.3 Influence of rice seed priming on growth parameters in lowland conditions

TP	NTS	NLS	PHS(cm)
Control	7.22 ± 0,55^{b}	43.17 ± 1.58^{c}	30.28 ± 1.67^{c}
NaCl	6.44 ± 0.86^{b}	40.78 ± 1,83^{d}	27.78 ± 1.44^{c}
Sucrose	9.22 ± 1.00^{a}	50.28 ± 2.85^{b}	50.72 ± 3.99^{b}
H_2O	9.50 ± 2.62^{a}	55.61 ± 3.88^{a}	54.06 ± 4.25^{a}
p	< 0.001	< 0.001	< 0.001

Legend: TP: Type priminge ; NTS :number of thalliat setting ; NLS : number of leaves at setting ; PHS : plant height at setting ; For a column, means (± standard deviation) followed by the same letter are statistically identical at the 5% threshold.

Table.4 Influence of priming on growth parameters under rainfed conditions

TP	NTS	NLS	PHS (cm)
Control	5.83 ± 0,62^{bc}	39.17 ± 1.47^{c}	23.50 ± 1.20^{c}
NaCl	6.39 ± 1.09^{bc}	39.06 ± 1.55^{c}	22.50 ± 1.29^{c}
Sucrose	6.78 ± 0.81^{b}	42.61 ± 3.05^{b}	31.50 ± 1.50^{b}
H_2O	8.44 ± 1.10^{a}	45.83 ± 3.70^{a}	34.06 ± 2.53^{a}
p	< 0.001	< 0.001	< 0.001

Legend: TP : Type priminge ; NTS : number of thalli at setting ; NLS : number of leaves at setting ; PHS : plant height at setting ; For a column, means (± standard deviation) followed by the same letter are statistically identical at the 5% threshold.

Table.5 Influence of priming on yield in lowland conditions

TP	W1G (g)	W1000G(g)	GY(kg/ha)
Control	0.0232 ± 0.0018^{c}	22.20 ± 0.03^{c}	2362.17 ± 3.29^{c}
NaCl	0.0271 ± 0.0042^{b}	22.48 ± 0.25^{b}	2360.83 ± 2.74^{c}
Sucrose	0.0294 ± 0.0055^{b}	23.84 ± 0.55^{b}	3666.67 ± 2.97^{b}
H_2O	0.0331 ± 0.0031^{a}	24.29 ± 0.38^{a}	4222.50 ± 062^{a}
p	< 0.001	< 0.001	< 0.001

Legend: TP: Type of priming; W1G: Weight of 1 grain; W1000G: Weight of 1000 grains (g);GY: Grain Yield; For a column, means (± standard deviation) followed by the same letter are statistically identical at the 5% threshold.

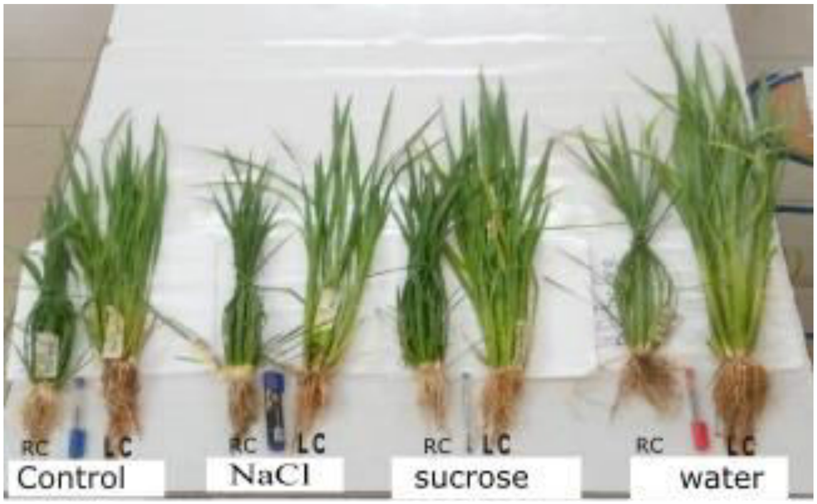
Table.6 Influence of priming on yield under rainfed conditions

TP	W1G (g)	W1000G(g)	GY (kg/ha)
Control	0.0183 ± 0.0010^{c}	16.51 ± 0.54^{d}	1353.83 ± 2.26^{d}
NaCl	0.0204 ± 0.0007^{b}	18.23 ± 0.36^{c}	1380.74 ± 0.77^{c}
Sucrose	0.0202 ± 0.0003^{b}	21.24 ± 0.47^{b}	2400.81 ± 0.82^{b}
H2O	0.0213 ± 0.0012^{a}	22.61 ± 0.32^{a}	2844.62 ± 042^{a}
p	< 0.001	< 0.001	< 0.001

Legend: TP: Type of priming; W1G: Weight of 1 grain; W1000G: Weight of 1000 grains (g); GY: Grain Yield; For a column, means (± standard deviation) followed by the same letter are statistically identical at the 5% threshold.

Figure.1 Seed of the C26 variety used

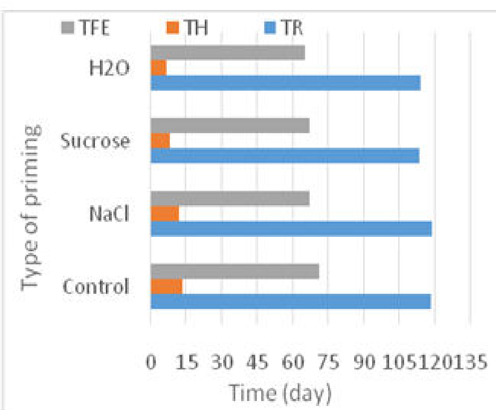
Figure.2 Plants from the beginning of the day



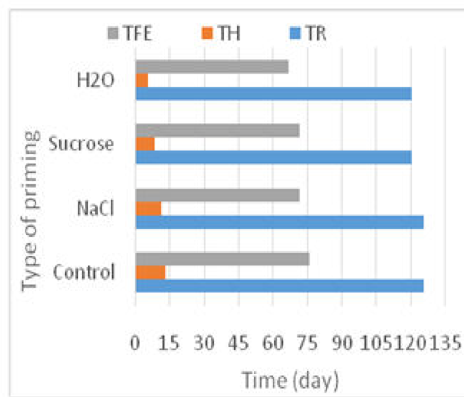
***Legend:** LC: lowland conditions; RC: rainfed conditions; Control: seedlings from unprimed seeds; NaCl: seedlings from seeds primed in NaCl solution; Sucrose: seedlings from seeds primed in sucrose solution; Water: seedlings from seeds primed in water.*

Figure.3 Influence of priming type on time to first ear (TFE), time to heading (TH) and time to ripening (TR)

a: lowland conditions



b: rainfed conditions



The priming would have induced a spontaneous modification of the characteristics of the C26 rice variety used, in order to improve its performance. In this sense, Farooq *et al.,* (2006) explained that in rice, this improvement in stem growth and optimization of thallus number through accelerated DNA replication and cell enlargement. In fact, the high growth rates induced by hydropriming can be explained by the fact that water stimulates endo-β-magnanage activity. These authors indicate that the increase in the number of thalli results from good development. Similar results had been obtained by Konan (2022), who asserted that rice growth is rapid with hydro-hammering in lowland conditions. The slowdown or drop in growth parameters between the control and NaCl in both systems (lowland and rainfed upland) can be explained by the fact that rice is a glycophytic species whose agronomic parameters are slowed by contact with low salt concentrations. This study is in line with that carried out by Gama *et al.,* (2007). These authors assert that very low salt concentrations influence all agronomic parameters of glycophytic species.

The waiting time for germination is shorter with water priming than with sucrose priming in both cropping systems. In fact, the positive effects that appear during emergence are reflected in rice development, flowering and ear formation. In addition, seedlings from unprimed grains develop more evenly. Giri and Schilinger (2003); Zarei *et al.,* (2011) revealed an improvement in heading growth and maturity of rice from hardened seeds, the effect of which was due to the synchronization of germination. Thus, priming corresponds to acclimatization insofar as it relates to physiological changes. This acclimatization enables the individual to live and reproduce autonomously under stress (Hopkins, 2003).

The best yields were obtained with water and sucrose priming. This was due to the fact that the rice plants underwent normal, vigorous development with an optimum number of thalli raised in both cropping systems. Based on similar results, Andriankaja (2001) explained that rice yield is a function of the number of thallus emitted. Optimizing thallage is therefore an important factor in increasing productivity. The permanent presence of water favors photosynthetic activity, enabling good development, and hence better rice yield in lowland conditions than in upland conditions.

This work was proposed to help improve rice production using the priming technique in lowland and rainfed upland cropping systems in a context of climate change. This study revealed that there was no significant difference between priming with NaCl and the control (unprimed) in the two cropping systems. A reduction in the ripening cycle was obtained with both water and sucrose priming in both culture conditions. In the lowland, sucrose and water priming resulted in a better emergence percentage of 95%.

Emergence time at 50% varied between 6 and 11 days, depending on the priming solution. Water and sucrose priming increased the number of thalli and plant height by around 2 thalli and 20 cm respectively. Yield was improved by around 50% with both water and sucrose priming. Under plateau conditions, emergence percentages ranged from 90 to 96%. Depending on the priming solution, the 50% emergence time varied between 3 and 5 days. The number of thalli and plant height increased by around 2 thalli and 3 cm respectively. Yield increased by around 50% with sucrose and water priming.

In short, the study shows that priming with water and sucrose significantly improves the agronomic performance of rice variety C26 in both lowland and rainfed uplands.

Prospects for the future include studying the effect of these primings on susceptibility to pathologies in these two cropping systems, on the one hand, and to water deficit, on the other.

Author Contribution

Badoua Badiel: Investigation, formal analysis, writing—original draft. Tchoa Koné: Validation, methodology, writing—reviewing. Pascal Adama Kihindo:—Formal analysis, writing—review and editing. Nestor Ouedraogo: Investigation, writing—reviewing. Etmongomaké Koné: Resources, investigation writing—reviewing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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